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ABSTRACT

This bulletin examines the narrowing margin between global food production and population growth. Between 1950 and 1971, world grain production nearly doubled and per capita production increased 31 percent. During the 1970s, gains in output barely kept pace with population growth, consumption per person declined in sub-Saharan Africa and parts of Asia, food prices were volatile, and over 100 food-deficit countries came to depend on the exportable surplus of North America, now the only major grain-exporting region. The world fish catch leveled off in the early 1970s and beef production, still dependent mainly on grassland grazing, leveled in the mid 1970s. With little new land left to plow, satisfying increased food demand now depends on sharp increases in yields on existing cropland. Worldwide, this effort is hampered by loss of topsoil and irrigation land, conversion of cropland to nonfarm uses, rising energy costs, inefficient agrarian structures (particularly in the Soviet Union), the falling yield responses to chemical fertilizers in agriculturally advanced countries, and the emerging competition between food and agriculturally based energy crops. Green Revolution successes in some developing countries demonstrate that, given the right inputs, Third World farmers can increase crop yields dramatically. Most important in meeting food needs on a finite planet is slowing population growth. (Author)

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POPULATION BULLETIN

World Food Resources and Population: The Narrowing Margin

By Lester R. Brown

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Abstract—This *Bulletin* examines the narrowing margin between global food production and population growth. Between 1950 and 1971, world grain production nearly doubled and per capita production increased 31 percent. During the 1970s, gains in output barely kept pace with population growth, consumption per person declined in sub-Saharan Africa and parts of Asia, food prices were volatile, and over 100 food-deficit countries came to depend on the exportable surplus of North America, now the only major grain-exporting region. The world fish catch leveled off in the early 1970s and beef production—still dependent mainly on grassland grazing—leveled in the mid-1970s. With little new land left to plow, satisfying increased food demand now depends on sharp increases in yields on existing cropland. Worldwide this effort is hampered by loss of topsoil and irrigated land, conversion of cropland to nonfarm uses, rising energy costs, inefficient agrarian structures, particularly in the Soviet Union, the falling yield response to chemical fertilizers in agriculturally advanced countries, and the emerging competition between food and agriculturally based energy crops. Green Revolution successes in some developing countries demonstrate that, given the right inputs, Third World farmers can increase crop yields dramatically. Feeding the world's poor also requires more equitable income and food distribution, including a reduction in the proportion of grain and fish consumed indirectly as livestock products by the affluent. Most important in meeting food needs on a finite planet is braking population growth. The author concludes that every effort should be made to stabilize world population at about six billion by 2020, rather than 10.5 billion by 2110 as now projected by the United Nations.

Editor: Jean van der Tak

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World Food Resources and Population: The Narrowing Margin

By Lester R. Brown

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POPULATION BULLETIN

Vol. 36, No. 3, September 1981

World Food Resources and Population: The Narrowing Margin

By **Lester R. Brown**
Worldwatch Institute
Washington, D.C.

Lester Brown is president and a senior researcher of the Worldwatch Institute of Washington, D.C. As administrator of the International Agricultural Development Service of the U.S. Department of Agriculture from 1966 to 1969, he coordinated programs to increase food production in 40 developing countries. He was a senior fellow with the Overseas Development Council from 1969 to 1974. He has been a member of the Advisory Committee of the Population Reference Bureau since 1975. Mr. Brown is author of several hundred articles, nine Worldwatch Papers, and several books, including By Bread Alone, In the Human Interest, *and* The Twenty-Ninth Day.

Most of this Population Bulletin *is drawn, with permission, from the Worldwatch Institute book by Mr. Brown,* Building a Sustainable Society *(Norton, October 1981), in which the world food problem and its solution are seen as major elements in efforts to create a sustainable society. Financial support for the book was provided by the United Nations Fund for Population Activities. This* Bulletin *also updates the world food situation discussed by Mr. Brown in the popular* Population Bulletin *(Vol. 29, No. 2) entitled, "Population and Affluence: Growing Pressures on World Food Resources," published in 1973 when world food shortages reached crisis proportions.*

In 1973, world food shortages reached crisis proportions with poor rice harvests in Asia, a shortfall in the Soviet Union's wheat crop, drought in sub-Saharan Africa, and disappearance of the anchoveta off the coast of Peru. Prices for some principal food commodities—wheat, rice, feedgrains, and soybeans—soared to historic highs in international markets.

The crisis was not an aberration. Rather it was a symptom of "fundamental long-term trends and forces that are altering the nature and dimensions of the world food problem," I wrote in a *Population Bulletin* of that year, "Population and Affluence: Growing Pressures on World Food Resources." The dominant cause of increased demand for food was still population growth, then at 1.8 percent a year overall, a rate that was adding 70 million annually to a global population of 3.9 billion. To this had recently been added increased demand for livestock products spurred by rising affluence in the United States and in the tier of industrial countries stretching across northern Europe through the Soviet Union to Japan.

World food production had soared between 1950 and 1970 but because of unprecedented population growth little progress had been made in raising per capita consumption of cereals. High hopes for increasing food stocks lay with the "green revolution." New high-yielding varieties of wheat and rice introduced in the late 1960s were boosting harvests dramatically in India, Pakistan, Turkey, the Philippines, Indonesia, Malaysia, and Sri Lanka. Counterbalancing this optimism, however, was growing recognition of emerging barriers to increased global food production such as the ac-

Frontispiece photo credits, see page 38.

celerating worldwide loss of topsoil exacerbated by deforestation.

By 1973, North America had emerged as the world's breadbasket. But the crisis of that year, coming on top of a series of threatened famines, nearly exhausted the world grain surpluses accumulated in the 1950s and 1960s which were concentrated mainly in the United States and all but a fraction of the 50 million acres of cropland idled under U.S. government programs were brought back into production. The post-World War II quarter-century of stable wheat, feedgrain, and soybean prices was coming to an end, I predicted, and "there is every prospect of very volatile world prices for the important food commodities." Also, "The world is moving from a situation of chronic excess agricultural production capacity to one of chronic scarcity."

Now, in 1981, those conclusions, based on trends perceptible in the early 1970s, are reinforced by other newly recognized trends that could undermine world food security if left undeflected.

The situation in 1981

Analysis by the United Nations has now revealed that the rate of annual world population growth peaked at about 2 percent in the mid-1960s and is currently down to a little over 1.7 percent.[1] But because of the much larger population base—4.5 billion in 1981—the annual gain in absolute numbers is up nearly to 80 million and is projected to rise close to 90 million by the year 2000, even with a further fall in the growth rate to 1.5 percent. Fertility is falling rapidly in some less developed countries, most notably China. But the less developed countries as a group minus China are still growing at 2.4 percent annually, a rate that, if sustained, would double their current 2.4 billion population in 29 years.

Globally, food production grew marginally faster than population during most of the 1970s. But consumption per person declined in sub-Saharan Africa and in parts of Asia. There were some outstanding successes. India, for example, after a string of good harvests, managed to feed its own population following the severe drought of 1979, though in 1981 it was forced to turn once again to the U.S. wheat market to replenish diminished government reserves. Worldwide, the number of undernourished people has probably increased. Bangladesh, for example, reported in 1980 that 85 percent of its population consumed less than 2,122 calories per person per day—the minimum now used to define poverty—and 54 percent received less than 1,885 calories—the extreme poverty line. In India in 1978, nearly half of the population (48 percent) was living below the poverty line of 2,400 calories per person per day in rural areas and 2,100 calories in urban areas.[2] Currently, 26 sub-Saharan African countries with a population exceeding 150 million are reporting food shortages, according to the World Bank.[3] World grain reserves are down to a near-record low and no idled cropland remains in the United States to fill the gap. True to predictions, food prices have been volatile since 1973.

Unforeseen when I wrote in mid-1973 was OPEC's quadrupling of the price of oil at the end of that year, the start of a trend that has escalated the costs of fertilizer, pesticides, and irrigation in its wake. With the price of oil soaring as world petroleum reserves dwindle, crops that could supply alternative sources of liquid fuel are now competing with food crops for available cropland. Boosting agricultural yields continues to be hampered by soil erosion, desertification, and—it is now realized—the accelerating conversion of farmland to nonfarm uses worldwide. The leveling in the world's fish catch, first evident in the early 1970s, has now been confirmed. It is now known, too, that, with overgrazing, the long-term growth in beef production came to a halt in the mid-1970s.

Table 1. World Grain Production, Total and Per Capita: 1950-1980

Year	Population (billions)	Grain production (million metric tons)	Grain production per capita (kilograms)
1950	2.51	631	251
1960	3.03	863	285
1970	3.68	1,137	309
1971	3.75	1,237	330
1972	3.82	1,197	314
1973	3.88	1,290	332
1974	3.96	1,256	317
1975	4.03	1,275	316
1976	4.11	1,384	337
1977	4.18	1,378	330
1978	4.26	1,494	351
1979	4.34	1,437	331
1980 (prel.)	4.42	1,432	324

Sources: Population figures from United Nations (UN), Department of Economic and Social Affairs, *World Population Trends and Prospects by Country, 1950-2000: Summary Report of the 1978 Assessment* (New York: 1979); grain production figures from U.S. Department of Agriculture (USDA), Economics, Statistics and Cooperatives Service, unpublished data; 1980 estimate by Worldwatch Institute.

The mounting pressures on global food resources are only some of the threats now facing our society. But food is basic to human life itself and pressures on food resources demand immediate attention.

Loss of Food-Production Momentum

The middle of the 20th century was a watershed in the evolution of world agriculture. From the beginning of agriculture until 1950, most increases in food output came from expanding the area under cultivation. Since then, most have come from raising yields on existing cropland. This drive to raise yields has made agriculture increasingly energy-intensive. Chemical fertilizers, irrigation, and mechanization—the primary means of expanding production—are all energy-intensive. In effect, as the frontiers disappeared, farmers learned to substitute energy for land.

The disappearance of frontiers notwithstanding, mid-century also marked the beginning of an unprecedented growth in food production. Between 1950 and 1971, the world's farmers nearly doubled grain production from 631 million tons to 1,237 million tons (see Table 1). These 21 years were also impressive in per capita terms. World cereal production per person climbed from 251 kilograms in 1950 to 330 kilograms in 1971, a gain of 31 percent. Diets improved measurably in many

Third World countries, and consumption of livestock products climbed steadily throughout the industrial world.

Since 1971, gains in output have barely kept pace with population growth. Grain production per person has fluctuated widely but shown little real increase. Indeed, the per capita grain production of 324 kilograms in 1980, an unusually poor harvest year, was actually lower than the 330 kilograms of 1971 (Table 1). In Africa, the continent with the fastest population growth ever recorded, the growth in food production has been consistently below population growth. The first continent to experience a sustained decline in food output per person, it suffered a 14 percent decline during the 1970s.

The long postwar period of food-price stability came to an end with the massive Soviet wheat purchase in 1972. The largest food-import deal in history, it singled the beginning of a new era. Within months, the world price of wheat had doubled and famine had returned to the Indian subcontinent, Africa, and elsewhere after a quarter-century absence. As food prices have climbed, diets have deteriorated in some Third World countries, especially among landless rural laborers and the urban poor. In some industrial societies, tightening grain supplies have led to a drop in per capita consumption of beef and other livestock products.

Shortfalls in harvests prevented until 1976 a rebuilding of the world food reserves depleted in 1972. With some uncommonly good harvests in the late 1970s, the food situation then stabilized temporarily. But in 1980, a poor harvest in the Soviet Union and a mediocre one in the United States resulted in a drawdown of world food reserves to a near-record low. Inefficient agrarian structures, soil erosion, the conversion of prime cropland to nonfarm uses, the falling yield response to chemical fertilizers in the agriculturally advanced countries, and rising energy costs—all contributed to the slower growth in food output.

Eroding the Base of Foodgrain Production

Dwindling supply of new cropland

Historically, the expansion of cultivation has been closely tied to population growth. Responding to population pressures, farmers moved from valley to valley and continent to continent, gradually extending the area under cultivation. Today, one-tenth of the earth's land surface is under the plow and the promising settlement frontiers have all but vanished.

Over time, farmers have devised ingenious techniques such as irrigating, terracing, and fallowing for extending agriculture onto new lands. Irrigation enables farmers to grow crops where rainfall is low or unpredictable. Through the centuries, terracing has permitted extension of agriculture onto steep slopes as in Japan, China, and Nepal. In semiarid regions, such as the western Great Plains of North America and the drylands of the Soviet Union, land has been left fallow every other year to gather moisture or plowed in strips with alternate strips cropped and fallowed. In tropical areas where soils quickly lose their fertility when stripped of the dense vegetative cover, farmers have mastered shifting cultivation whereby land is cleared and cropped for three or four years and then abandoned for 20 to 25 years until the exhausted soils have revived. Now, under population-induced pressures, the time-tested practices of terracing and fallowing are being abandoned in many areas.

An analysis of data for grains only, which occupy some 70 percent of the world's cropland, shows rising land productivity accounting for close to four-fifths of the growth in world grain supplies from 1950 to 1980. Land planted to grain expanded by 152 million hectares,

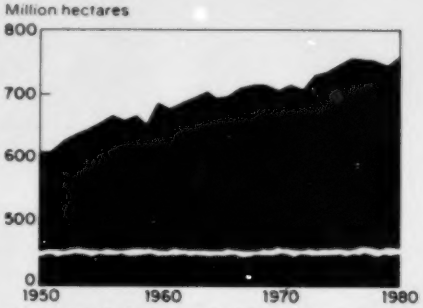
or some 25 percent, during this period (Figure 1). From 1951 to 1956, fully half of the increase came from the extension of grain production onto the "Virgin Lands" of the Soviet Union. In the next 16 years, the area planted in cereals increased only 7 percent worldwide as some 20 million of the then 140 million hectares (350 million acres) of cropland in the United States was idled under government programs because of excess production capacity.[4] With poor weather and short harvests, most of this land was returned to production between 1972 and 1976, accounting for at least one-third of the 7 percent world gain in that period. A smaller share came from reducing the amount of land fallowed in the United States and the Soviet Union and expanding the cultivated area in Argentina, Brazil, Nigeria, and other developing countries.[5]

With most of the world's good agricultural land already under the plow, the potential for expanding cropland provides little ground for optimism. In the United States, further increases in the cultivated area will not come easily now that the cropland once idled under government programs has been released for production.* Opportunities for developing new cropland are negligible in Western Europe and the Soviet Union and virtually nonexistent in Eastern Europe. India could stretch cropland use if the full irrigation potential of the Gangetic Plain is developed to permit multiple cropping. Both cropland area and multiple cropping could be increased in the Mekong Valley and Delta if political conditions permit.

In Africa, new cropland could be opened in the Sudan, which has developed only part of the Nile waters reserved to it by treaty with Egypt, and in the Tsetse Fly belt of Central Africa, if the disease-carrying fly can be eradicated.

*Michael Brewer, research director of the recently completed National Agricultural Lands Study, examines the current status of U.S. agricultural land in a forthcoming *Population Bulletin*.

Figure 1. World Harvested Area of Cereals: 1950-1980



Source: See Table 2, page 8. Note: 1 hectare = 2.47 acres.

Latin America could create croplands by plowing up some grasslands, though this would reduce grazing capacity. Brazil is currently developing the Cerrado, on the southern border of the Amazon Basin, although the fertility of the land is not particularly high. Brazil's efforts to develop pockets of potentially productive cropland within the Amazon Basin have been discouraged by failure of a colonization scheme launched with the opening of the Transamazon Highway in 1970. The goal was to settle a million families along the highway by 1980, but only 7,000 families had been successfully settled by then. Crop insects and disease, deteriorating soils, and costly road maintenance are contributing to the project's demise.[6]

On balance, it is difficult to envisage an increase in the world's cropland base of much more than 10 percent by the century's end. With projected population increases, this modest increase would leave us in the year 2000 with only .13 hectares (.32 acres) of cereal land per person, well below the .17 hectares (.42 acres) we each now have (see Table 2). Satisfying the two-thirds increase in the world food demand projected by the United Nations for the remainder of this century will thus

Table 2. World Population and Area in Cereals, 1950 and 1980, with Projections to 2000

Year	Population (billions)	Area in cereals (million hectares)	Area per person (hectares)
1950	2.51	601	.24
1980	4.42	758	.17
2000	6.20	828	.13

Note: 1 hectare = 2.47 acres.

Sources: Population figures from UN, *World Population Trends and Prospects by Country, 1950-2000*; area in cereals data from USDA, Economics, Statistics and Cooperatives Service, unpublished data and private communication, January 26, 1981.

require a sharp increase in the productivity of existing cropland. Thinning topsoil, desertification, the loss of irrigated land, and conversion of cropland to nonfarm uses will hamper this effort.

Agricultural land deterioration and loss

Thinning topsoil. Even though world grain output has more than doubled since 1950, that impressive increase has entailed land abuse so severe that fully one-fifth and perhaps as much as one-third of the world's cropland is losing topsoil at a rate that is undermining its long-term productivity.[7] In Washington, the Department of Agriculture reported in early 1981 that the inherent productivity of 34 percent of U.S. cropland is now falling because of the excessive loss of topsoil.[8]

For most countries, the growing demand for food is internally generated, but for the United States the stresses on soils come from growing food deficits worldwide. With the mounting demand for food combined with the availability of nitrogen fertilizer that was cheap until the price of oil took off, U.S. farmers abandoned traditional rotations that included soil-building pastures and hay in favor of continuous planting of corn and other row crops. Data gathered at the Missouri Agricultural Experiment Station show land planted to a corn-wheat-clover rotation losing an average of 2.7 tons of topsoil per acre annually through erosion, whereas comparable land planted continuously to corn lost 19.7 tons annually.[9] While the first loss is well within the tolerance range established by soil scientists, the latter leads to a progressive thinning of the topsoil layer and a steady decline in inherent land productivity. In Iowa alone, 260 million tons of soil are lost from cropland each year.[10]

Water erosion causes further loss. In the United States, water erosion alone removes some two billion tons of topsoil a year from croplands—1.01 billion tons more than is formed each year by natural processes.[11] Assuming 160 tons per acre inch of soil and a typical topsoil depth of 8 inches, this billion tons represents the loss of 781,000 acres of cropland equivalent per year.

In the Third World, record rates of population growth have forced farmers onto mountain slopes, leaving them no time to construct terraces. Once the natural cover is removed, the topsoil quickly washes into adjacent valleys where it silts streams, reservoirs, and canals. In mountainous Nepal, the country's rivers now annually carry 240 million cubic meters of soil to India, making that country the recipient of what has been described as Nepal's "most

precious export."[12] A U.S. Agency for International Development officer in the Punjab area of Pakistan reports the annual abandonment of several thousand hectares of cropland because of severe degradation caused by water erosion.[13]

In Andean Latin America, skewed land-ownership patterns can aggravate the problem. Wealthy ranchers use the relatively level valley floors for cattle grazing, forcing small landholders onto steep slopes to produce subsistence crops. This leads to severe soil erosion on the slopes, which impairs the productivity of both the mountainsides and the valleys.

Where fallowing and other restitutional agricultural practices have fallen by the way, compensatory measures can go only so far. In the Soviet Union, attempts to regain food self-sufficiency by investing heavily in agriculture are stymied because soils have lost some of their inherent productivity. Harvard University's Thane Gustafson, in an analysis of Moscow's agricultural plans, observes that the Soviet government must now reckon with "50 years of neglect that have left a legacy of badly damaged soils."[14] This, along with mismanagement in its collectivized agricultural system, has contributed to the Soviet Union becoming the world's single largest grain importer.

USDA

Eroded topsoil blows in a Colorado corn field.

In many Third World countries where firewood is the primary fuel, deforestation is a leading cause of soil erosion as well as devastating floods. In 1974, extensive flooding in Bangladesh, partly caused by progressive deforestation in the Nepalese and eastern Indian watersheds, sharply reduced the rice harvest and the ensuing famine claimed a third of a million lives.[15] Deforestation also reduces soil fertility indirectly. When firewood runs out, villagers turn to dried cow dung and crop residues for fuel, depriving soils of the nutrients contained in these traditional fertilizers.

Underscoring the gravity of the erosion threat is convincing evidence that adopting erosion-control practices is in most cases not cost-effective for the farmer. In southern Iowa, agricultural scientists calculated that the costs of reducing soil erosion to a tolerable level came to three times the immediate economic benefits of doing so.[16] Unless governments share the cost of erosion control, a typical farmer with a narrow profit margin would have to choose between adopting the costly measures needed to control erosion and facing bankruptcy or letting things go until the land's productivity fell so low that it would have to be abandoned.

Desertification. With overgrazing, deforestation, and overplowing in semiarid regions where human and livestock populations are expanding at record rates, desertification is also imperiling food production. Major deserts are growing larger in Africa, the Middle East, Iran, Afghanistan, and northwestern India. The Sahara, for example, annexed some 90 to 100 kilometers of the Sudan between 1958 and 1975.[17]

Of 16 desert countries, per capita grain output has fallen over the past three decades in all but four.[18] Iran, Libya, Senegal, and the Sudan have

been able to offset desertification with irrigation. Among the remaining 12 countries, the drop in per capita grain output in Algeria, Iraq, Jordan, Lebanon, Mali, and Niger was a precipitous 40 percent or more between 1950 and 1980.

Loss of irrigated land. Data compiled in a 1977 UN report indicate that one-tenth of the world's total irrigated area is waterlogged—some 21 million hectares.[19] The productivity of this land has fallen by an estimated 20 percent, and almost as much land has been rendered less productive by salinization.

Waterlogging and salinity occur whenever irrigated land has inadequate underground drainage. The water table is gradually raised. When it comes to within a few feet of the surface, the growth of deep-rooted crops is impaired. As it rises further, water begins to evaporate through the remaining few inches of soil, thereby concentrating the minerals and salt near the surface. Eventually, the concentrated salt inhibits plant growth. Salvaging the land costs $650 per hectare on average according to a recent UN estimate.

In the arid areas of the southern half of the Soviet Union and in the western United States, irrigated land is losing out to the demands of expanding cities and industries. In California, Los Angeles' thirst has left brown and abandoned fields that were once among the most productive in the world. Efforts to develop the extensive coal and oil-shale resources in the western United States will divert still more water from agriculture. Each of these new diversions of water from agriculture to other uses adds to the upward pressure on food prices. Eventually, irrigated agriculture could be eliminated in the western United States.

Irrigated agriculture is sure to be short-lived in the southern Great Plains of the United States. Accounting for much of the growth in U.S. irrigated acreage since 1945, this area now supports many of the country's largest beef feedlots, drawn by the unique combination of a dry climate and plentiful supplies of grain sorghum, corn, and alfalfa grown on irrigated land. That land, however, draws on the "fossil water" of the vast Ogallala aquifer which can't be refilled or recharged.

Conversion of cropland to nonfarm uses. Agriculture's principal competition for land comes from urban and village expansion, energy production, and highway construction. In the United States, the world's leading food producer, well over half a million acres of cropland were converted to nonfarm uses each year between 1967 and 1975.[20]

Growth of cities is a leading source of cropland loss. A study in Europe found that between 1960 and 1970 West Germany lost 1 percent of its agricultural land every four years to urban encroachment and France and the United Kingdom lost nearly 2 percent over the decade.[21] For the Third World, information on land lost to rapid urbanization is sketchier. But UN demographers expect the world's urban population to expand from 1.81 billion in 1980 to 3.16 billion in 20 years.[22] If this projected increase created a need of only .04 hectares per person, then the world's cities would occupy an additional 54 million hectares of land by 2000. If 40 percent of this total is converted cropland, cities would consume an area equal to the cultivated area of France.[23]

Although this projected loss would amount to less than 2 percent of the world's cropland, the impact on world food output is likely to be greater since cities are situated on the most fertile soils. A study in Canada reports that "half of the farmland lost to urban expansion is coming from the best one-twentieth of our farmland."[24] Of China, U.S. department of Agriculture China specialist Alva Erisman reports that "water control projects, urban growth, and the appropriation of agricultural land for roads, railroads, airfields, industrial plants, and military uses has removed

good farmland from cultivation."[25]

Rivaling urbanization as a claimant on cropland is energy production. Hydroelectric dams can inundate vast stretches of rich bottomland, even as they add to the irrigated area. An electric generating plant can cover hundreds of acres. As the world turns from oil to coal, the conflict between energy and food producers will intensify. In the United States, some of the most accessible reserves of coal are by an accident of geography directly beneath some of the nation's finest farmland. In Illinois, the heart of the Corn Belt, 81,891 hectares in 40 counties were reported to have been affected by surface and deep mining of coal by 1976.[26] Companies stripmining in the United States are now required by law to restore land to its original productive state, but doing so may be impossible in many situations. In 1977, the Department of Agriculture reported that "surface mining as practiced in much of the nation today either ruins farmland completely or reduces its production drastically."[27]

In the United States also, an enormous, if unmeasured, amount of cropland has been lost to parking spaces, streets, highways, and filling stations to accommodate the nation's 143 million licensed motor vehicles.

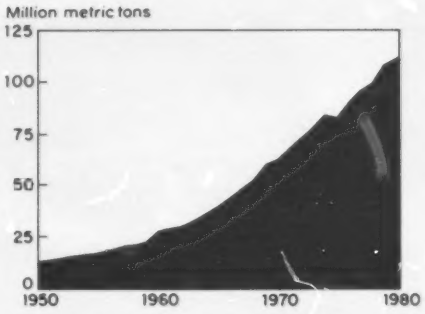
Commenting on the threat posed by the continuing conversion of cropland to nonfarm uses, former U.S. Assistant Secretary of Agriculture M. Rupert Cutler observes: "When farmland goes, food goes. Asphalt is the land's last crop."[28]

Substituting Fertilizer for Land

When German chemist Justus von Liebig discovered in the 1840s that all the nutrients that crops remove from the soil could be replaced, he set the stage for the extensive substitution of chemical fertilizer for land as the frontiers closed. Since 1950, the expanding use of chemical fertilizer has been the principal source of growth in world food output. Increasing the use of irrigation, pesticides, and improved seeds has contributed to that growth, but without chemical fertilizer, world food output would likely fall by at least a third.

The three basic plant nutrients that can readily be supplied to the soil as chemical fertilizers—nitrogen, phosphorous, and potassium—all require substantial amounts of energy to mine or synthesize and to transport. Particularly large amounts of energy are required to synthesize atmospheric nitrogen into stable compounds that can be used for fertilizer. Oil along with natural gas has been the source of that energy and it was the availability of cheap oil that helped underwrite the unprecedented increase in food production during the immediate postwar decades. In 1950, the world's farmers applied some 14 million tons of chemical fertilizer to the soil. By 1980, they were using 113 million tons—an eightfold increase over a three-decade span (see Figure 2). At mid-century, worldwide fertilizer use averaged less than 6 kilograms per person, but by 1980, it had

Figure 2. World Fertilizer Consumption: 1950-1980



Source: See Table 3, page 12.

Table 3. World Grain Production and Fertilizer Use: 1934-38 to 1978-80

(Numbers in million metric tons)

Period	World grain production	Increment	World fertilizer use	Increment	Incremental grain/fertilizer response ratio
1934-38	651		10		
1948-52	710	59	14	4	14.8
1959-61	848	138	26	12	11.5
1969-71	1,165	317	64	38	8.3
1978-80	1,451	286	106	42	6.8

Sources: Grain production figures from USDA, Economics, Statistics and Cooperatives Service, unpublished data, and an estimate for 1980 production by Worldwatch Institute; fertilizer use figures from USDA, Economic Research Service, unpublished data and private communication, May 27, 1981.

climbed to nearly 26.

Crop yields increase predictably with each increment of chemical fertilizer—rapidly at first, then more slowly until they eventually level off. Understanding this fertilizer-response curve is key to understanding future food production prospects. Between 1934 and 1938, world grain production averaged 651 million tons per year and fertilizer consumption a rather modest 10 million tons. From then until 1950, fertilizer consumption increased by only 4 million tons. But after 1950 as growth in the cultivated area slowed and world population growth accelerated, fertilizer consumption began to grow by leaps and bounds. During the 1950s, each additional million tons of fertilizer use was associated with an increase in the world grain harvest of over 11 million tons (see Table 3). During the 1960s, the response declined to 8.3 million tons of grain. For the 1970s, the response was lower still—an additional million tons of fertilizer yielded only 6.8 million tons of additional grain.

In countries like the Netherlands and Japan and in the U.S. Corn Belt, the use of chemical fertilizer is close to the saturation point and further increases will not appreciably increase yields, barring a marked improvement in the capacity of cereals to utilize fertilizer. In such countries as India and Argentina, where fertilizer application rates are still low, the response to additional applications of fertilizer is high.

While future fertilizer requirements cannot be projected precisely, the amount of fertilizer required per capita to satisfy future food needs is certain to increase if population growth continues. As long as the cropland per person continues to shrink, the amount of fertilizer needed per person will rise. This will increase pressures on the world's dwindling supplies of oil and natural gas and escalate the cost of food production as the price of oil continues to soar. Whatever the cost, much more chemical fertilizer will be needed in developing countries if their crop yields are to increase. As pointed out by Norman Borlaug, Nobel Peace Prize winner for his work in developing the high-yielding wheat varieties of the green revolution, "Chemical fertilizers are especially essential to restore productivity to the 'mined out, tired' soils' which are typical of most of the developing nations."[29] For the foreseeable future, Borlaug believes, it is impossible for these nations to replace chemical fertilizer with supplies of organic fertilizer—from animal manure or nitrogen-fixing plants—that would be adequate to meet the food needs of their growing millions.

Leveling of Fish and Beef Production

Fish

Similar to the diminishing returns to applications of fertilizer worldwide, increasingly heavy investments in fishing capacity by governments and corporations have failed to increase the world's fish catch appreciably since 1970 and per capita consumption has declined. This has dampened the long-held hope that when land-based food supplies become inadequate, humanity could turn to the oceans for food.

Reflecting the growing human appetite for protein since mid-century, the world's fish catch more than tripled between 1950 and 1970, an increase of some 5 percent a year.[30] By 1970 the world catch totaled 68 million tons, including the inland fresh water catch and fish-farming, which together accounted for a tenth or more of the total. At this point, the world's fisheries were supplying more meat for human consumption than its cattle herds. Worldwide the catch averaged 18.5 kilograms, or 40 pounds (fresh weight) per person in 1970, although people in some affluent industrial countries, particularly Japan and the Soviet Union, were consuming easily twice the global per capita average while some landlocked Third World countries had fishless diets.

Part of the world's fish catch is consumed as protein meal by livestock, principally hogs and poultry (Table 4). Most species reserved for pigs, chickens, and other livestock are those that people don't relish, such as anchovies. But at some point livestock and people begin to compete for fish. Between 1950 and 1970, the share of the catch used for fishmeal increased from one-sixth to over one-third, a high point that coincided with the peak of the anchovy catch. Since 1974 the world fish catch appears to be leveling off at just over 50 million tons for food and some 21 million tons for fishmeal. By 1980, the combined average per person was 16.1 kilograms, a drop of 13 percent in ten years (Table 5, page 14).

Table 4. World Fish Catch, Food and Nonfood Uses: 1960-1979

(Numbers in million metric tons)

Year	Food	Fishmeal	Total
1950	18.1	3.0	21.1
1955	24.3	4.6	28.9
1960	31.4	8.6	40.0
1965	37.2	16.3	53.5
1970	42.6	25.5	68.1
1971	43.9	24.6	68.5
1972	45.0	19.2	64.2
1973	47.5	17.6	65.1
1974	48.9	20.6	69.5
1975	49.0	20.3	69.3
1976	50.7	22.1	72.8
1977	52.8	19.7	72.5
1978	52.8	21.0	73.8
1979 (prel.)	52.5	20.9	73.4

Sources: Food and Agriculture Organization of the United Nations (FAO), *Yearbook of Fishery Statistics: Fishery Commodities*, annual volumes 1960-1978 (Rome: 1961-1979); 1974-1979 total catch from FAO, Fisheries Department, *Fishery Commodity Situation and Outlook 1979/80*, FAO Fisheries Circular No. 728, May 1980; 1974-1979 food and fishmeal totals derived by Worldwatch Institute from data in FAO, *Yearbook of Fishery Statistics: Fishery Commodities 1978* (Rome: 1979).

Overfishing has become the rule, not the exception, in oceanic fisheries, but it is often discovered after the fact—when the catch in a given fishery begins to decline precipitously. Since the late 1960s in the northwest Atlantic, the decline in the catch has ranged from 40 percent for herring to over 90 percent for halibut. Abetted by a shift in the Humboldt current, the anchovy catch off the coast of Peru collapsed in the early 1970s from 12 million tons to 2 million a year, where it has remained into the 1980s.[31]

Efforts by the international commu-

Table 5. World Production Per Capita of Fish and Beef: 1960-1980

(Numbers in kilograms per person)

Year	Fish	Beef
1960	13.2	9.32
1961	14.0	9.62
1962	14.9	9.85
1963	14.7	10.74
1964	16.1	10.06
1965	16.0	9.92
1966	16.8	10.20
1967	17.4	10.38
1968	18.0	10.67
1969	17.4	10.70
1970	**18.5**	10.60
1971	18.3	10.37
1972	16.8	10.56
1973	16.8	10.46
1974	17.7	10.97
1975	17.2	11.28
1976	17.7	**11.58**
1977	17.3	11.52
1978	17.3	11.36
1979	16.9	10.88
1980 (prel.)	16.1	10.53

Note: Peak years in boldface.

Sources: Compiled by Worldwatch Institute, using data on fisheries from FAO, *Yearbook of Fishery Statistics: Catches and Landings*, annual volumes 1960-1978 (Rome: 1961-1979), and private communication with FAO Washington, D.C., office, June 3, 1980; data on beef production (including buffalo) from FAO, *Publication Yearbook*, annual volumes 1960-1979 (Rome: 1961-1980), and private communication with FAO Washington, D.C., office, June 4, 1980; and population figures from UN, *World Population Trends and Prospects by Country 1950-2000*.

nity to create an international body with authority to manage fisheries have failed. However, a potential solution to the fisheries' problem has evolved with the concept of Exclusive Economic Zones under which coastal states have extended offshore limits from the traditional three to 12 miles to 200 miles. By 1979, a UN Food and Agriculture Organization survey of 132 coastal states showed that 93 claimed jurisdiction beyond 12 miles, 78 of them claiming limits of 200 miles.[32] By FAO estimates, some 99 percent of the world seafood catch is taken within 200 miles. Under the doctrine of Exclusive Economic Zones, countries with technologically advanced fishing fleets lose their long-held advantage over coastal states. Between 1978 and 1979, the Japanese fleet's catch fell by 7 percent and the Soviet Union's by 4 percent, although the world catch was essentially unchanged.[33]

Besides overfishing, pollution has eroded seafood stocks from the oysters of Chesapeake Bay of the U.S. east coast and the Arcachon Bay of France to the mackerel of the Black and Azov Seas. Surrounded by the Soviet Union, Turkey, Romania, and Bulgaria, the Black and Azov Seas are reported to be "almost lifeless" and the original stock of 50,000 to 100,000 tons of mackerel has disappeared.[34]

Some hope for offsetting fish catch declines rests in the potential for exploiting untraditional species such as kapelin and sprat in the northern Atlantic and pollock in the northern Pacific. Krill—a small, shrimp-like Antarctic crustacean—could also become important, although its habitat is far from the world's population centers and means must be found to convert it into a palatable, commercially attractive product.

Projections of the world's future oceanic fish catch have been lowered. The U.S. Government's *Global 2000 Report*, published in 1980, concluded that the generally accepted annual potential of 100 million metric tons of traditional marine species probably cannot be achieved on a sustained basis.[35] More likely, says the report, the sustainable oceanic catch is close to 60 million metric tons. Optimistically, we could project a harvest of 85 million tons by the year 2000, assuming that management of fisheries improves, the few remaining underexploited stocks are fully developed, and fish-farming doubles. Even at that level, the

catch per person would be 13.7 kilograms—a 30 percent decline from the 18.5 kilograms of 1970.

Beef

The story of the world's fish catch is being repeated with beef production.

Beef and dairy cattle make up 1.21 billion of the world's nearly three billion domesticated ruminants.[36] Like water buffalo, sheep, and goats, they are supported almost entirely on agricultural land too dry or too steeply sloping to sustain cultivation. Twenty-three percent of the earth's land surface (3.1 billion hectares)—roughly double the area in crops—is devoted to livestock grazing.

Ruminants depend only in small part upon grain. Even in the United States where feedlots are quite common, forage still amounts to 82 percent of all feed units consumed by beef cattle, 63 percent of the total consumed by dairy cattle, and 89 percent of that consumed by sheep and goats.[37] Elsewhere, the share of roughage in the ruminant diet is much higher. In India, for example, only 3 percent of the grain harvest goes to feed livestock.[38]

UNICEF

A government fish farm in Bangladesh. Despite increased investments in fishing capacity, the world fish catch has leveled since 1974 and per capita consumption has declined.

From early Biblical days until recently, livestock numbers have grown along with human populations. After World War II, population growth, interacting with rising incomes, led to a vast increase in the demand for livestock products—meat, milk, cheese, and butter. Between 1950 and 1976, world beef production more than doubled.[39] Production per capita rose from 9.32 kilograms in 1960 to 11.58 in 1976 (Table 5). Since then, total beef production has leveled off and per capita production fell to 10.53 kilograms in 1980. The expansion of herds and flocks is overtaxing the earth's grass and rangelands, making it impossible for them to continue to expand apace with human numbers.

With overgrazing, grasslands deteriorate progressively. Sheep replace cattle as pastures decline in quality and eventually goats replace sheep. Vegetation disappears entirely in extreme cases as in many regions of the Middle East where populations are now multiplying at record rates.

U.S. grazing land also shows signs of overgrazing. The Bureau of Land Management reported in 1975 that 50 million acres of the 163 million acres of rangeland it manages were in "poor" or "bad" condition—stripped of most or virtually all topsoil and vegetative cover.[40] A recent U.S. Department of Interior study reports that severely degraded lands produce less than 9 pounds of beef per acre per year compared to 14 pounds on "good" rangeland.[41]

Beef herds would probably have hit their limits sooner except for the fact that more and more of the world's beef cattle were being "finished for market" in feedlots. This shifted some of the pressure from grasslands to corn fields. But now as mounting demands for grain drive prices upward, grain is not likely to be cheap enough again to use to relieve the pressure on grasslands.

The per capita decline in the yield from the world's fisheries and beef

herds indicates that expanding human demands are overtaxing earth's life-support systems. Averages obscure wide variation in individual consumption, but they do help us put our resource use in a population perspective. As long as the per capita average is climbing, everyone has at least a theoretical chance of consuming more. But once the global average turns downward, if some people are to consume more, others must consume less. In such a situation, the unmet basic needs of the poor can be satisfied only if the affluent consume less.

The North American Breadbasket

More and more countries in which grain production has not kept pace with demand have come to rely on the exportable surplus of North America (the United States and Canada). As seen in Table 6, Western Europe was the only grain-importing region prior to World War II. North America was not the only exporter nor even the leading one. During the late 1930s, Latin American grain exports were nearly double those of North America, and Eastern Europe (including the Soviet Union) was exporting 5 million tons annually, the same amount as North America.

All this has now changed beyond recognition. Asia has developed a massive deficit. Africa, Latin America, and Eastern Europe all import grain. Western Europe, consistently importing 15 to 30 million tons, has been the most stable element throughout the period. North America's emergence as the world's breadbasket began in the 1940s. The scale of exports expanded gradually during the 1950s and 1960s, but then more than doubled during the 1970s as scores of countries began to lose the capacity to feed themselves. In 1980, net grain exports from North America totaled 131 million tons compared to 14 million in 1950 (Table 6). Almost 40 percent of the region's harvest is now exported.

This dramatic transformation of intercontinental food flows reflects wide differences in population growth, widely varying levels of agricultural management, and, in many countries, a rate of soil erosion that is draining cropland of its fertility. As recently as 1950, for example, North America and Latin America had roughly equal populations —163 and 168 million, respectively. By 1980, North America had 247 million and Latin America had 360 million.[42] North America's population growth has tapered off substantially since 1950 while Latin America's has escalated. In 1980, population growth rates were close to 3 percent per year in Mexico, Venezuela, Peru, and Brazil. Had North America's 1950 population expanded at 3 percent per year, it would have reached 395 million in 1980 and absorbed virtually all the region's exportable surplus, leaving it struggling to maintain self-sufficiency.

Today, over 100 countries rely on North American grain. The worldwide movement of countries from export to import status is a much traveled one-way street. The reasons vary, but the tide is strong. No country has gone against it since World War II. Literally scores of countries have become food importers, but not one significant new exporter has emerged.

Not only are more countries joining the legions of importers, but the degree of reliance on outside supplies in growing. More and more nations, both industrial and developing, are importing more food than they produce. Among the countries that now import over half of their grain supply are Algeria, Belgium, Japan, Lebanon, Libya, Saudi Arabia, Senegal, Switzerland, and Venezuela. Other countries rapidly approaching primary dependence on imported foodstuffs include Costa Rica, Egypt, Portugal, South Korea, and Sri Lanka.[43]

For most countries, the need for

Table 6. The Changing Pattern of World Grain Trade: 1934-38 to 1980

(Numbers in million metric tons)

Region	1934-38	1948-52	1960	1970	1980
North America (U.S. and Canada)	+ 5	+23	+39	+56	+131
Latin America	+ 9	+ 1	0	+ 4	- 10
Western Europe	-24	-22	-25	-30	- 16
Eastern Europe and USSR	+ 5	0	0	0	- 46
Africa	+ 1	0	- 2	- 5	- 15
Asia	+ 2	- 6	-17	-37	- 63
Australia and New Zealand	+ 3	+ 3	+ 6	+12	+ 19

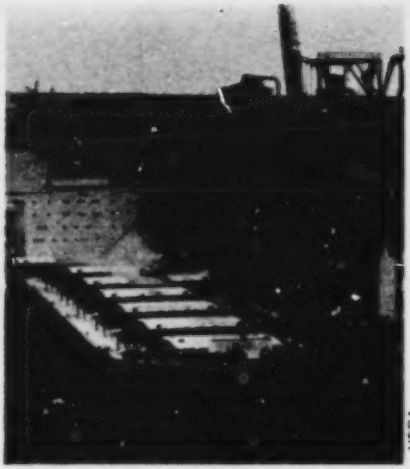
Note: Plus sign indicates net exports; minus sign, net imports.

Sources: 1934-38 through 1970 from Lester R. Brown, *The Twenty-Ninth Day* (New York: Norton, 1978), based on data from U.S. Department of Agriculture; 1980 figures from USDA, Foreign Agricultural Service, *Foreign Agriculture Circular*, FG-35-80, December 12, 1980, adjusted by Worldwatch Institute.

imported food is more likely to increase than decrease. Agricultural mismanagement and inefficiency have taken their toll on food production, particularly in the Third World and the centrally planned economies of Eastern Europe. It is difficult, for example, to see how the Soviet Union can avoid importing even more grain in the near future. In the late 1930s, the Soviet Union and Eastern Europe still had a regional export surplus of several million tons of grain yearly. But since then, the food balance has slowly shifted. Throughout the 1960s, the Soviet Union teetered on the brink of food self-sufficiency, sometimes as exporter, sometimes as importer. But with Moscow's decision in 1972 to offset crop shortfalls by importing grain rather than by slaughtering the livestock herds, the Soviet Union emerged as a chronically food-deficit country. During the mid-1970s, grain imports averaged 9 million tons per year. Late in the decade, they were averaging some 20 million tons per year.[44] Even though U.S. grain shipments to the Soviet Union were restricted in January of 1980 following the Soviet invasion of Afghanistan, the Soviets began the new decade by importing 31 million tons of grain in its first year, more than any country in history.

Although the Soviet Union has the largest cropland area of any country, the inefficiency of its agricultural system represents a problem Moscow planners seem unable to solve. The factory-style organization of agriculture on the state farms and the size of collectives weaken the key link between effort and reward for those who work the land. Consequently, production on Soviet agricultural collectives and giant state farms cannot approach that of the family-farm system that dominates West European and North American agriculture.

Other countries also face rapidly growing deficits. Egypt has little opportunity for expanding its agricultural base and yet its 1981 population of 44 million will double in 23 years if the current 3 percent annual growth rate continues.[45] According to International Food Policy Research Institute projections, Nigeria will have a food deficit of at least 17 million tons of grain annually by 1990 if recent trends continue. Mexican grain imports are growing by leaps and bounds, and unless Mexico loses an even larger fraction of its population through illegal migration to the United States, this trend is likely to continue.[46] The story is fundamentally the same in scores of countries.



USDA

Loading grain for export in the Port of New Orleans. More than 100 food-deficit countries now rely on North American grain.

Although the need for imported grain is projected to continue growing, the capacity of North America to respond to these demands may ultimately be overwhelmed. The disappearance of idled cropland, the growing use of U.S. grain in alcohol fuel distilleries, and the projected decline in irrigated acreage in key U.S. farm states will all make it more difficult to sustain the rapid growth in North American exports on which the world has none too wisely come to depend.

Behind this trade issue, a philosophical debate is beginning to emerge on the wisdom of mining soils in order to meet the ever growing world demand. Many U.S. agricultural analysts and environmentalists now argue that it makes little sense to sacrifice a resource that has been a source of economic strength since colonial days merely to raise the foreign exchange necessary to buy a few billion barrels of oil. Others contend that the current generation of farmers has no right to engage in the agronomic equivalent of deficit financing and thus mortgage the future of generations to come. The current trend is fraught with risks for both those whose livelihoods depend on land being productive and for those in countries dependent on food imports that will dry up if the mining of North American soil continues. Even for the importers, lower imports and a reduction in pressure on North American soil resources in the short term would be better than losing the region's exporting capacity over the long run.

Growing Food Insecurity

From the late 1940s through the early 1970s, the world enjoyed an unprecedented period of food security. Carryover stocks of grain, held largely by the principal exporters, and cropland idled under farm programs in the United States accounted for that security. Grain carryover stocks—the grain in bins when the new harvest begins—were available for use when needed. Idled U.S. cropland could be brought back into production within a year. Together, these two reserves provided a security for all the world's people, a cushion against any imaginable disaster.

As recently as 1969, the amount of grain that either was held in storage or that could be produced within a season on idled U.S. cropland amounted to 91 days of world consumption. Following poor harvests in key producing countries in 1972 and 1974, world reserves fell to only 40 days (see Table 7). At this level, grain stocks constituted little more than pipeline supplies, barely enough to fill the supply line between the farmer and the ultimate consumer.

The world enters the 1980s with only one of the two traditional reserves—carryover stocks of grain. For the first time in a generation, there is no cropland idled under U.S. government programs. The loss of this reserve, which provided security for the entire world, may be permanent. Carryover stocks of grain in 1980 amounted to 40 days of consumption. Except for 1974 and

Table 7. Index of World Food Security: 1960-1980

Year	Reserve stocks of grain	Grain equivalent of idled U.S. cropland	Total reserves	Reserves as days of world consumption (days)
	(million metric tons)			
1960	198	36	234	102
1965	143	70	213	80
1970	165	71	236	77
1971	183	46	229	73
1972	142	78	220	66
1973	147	25	172	51
1974	132	4	136	40
1975	138	3	141	40
1976	192	3	195	55
1977	191	1	192	51
1978	218	21	239	62
1979	191	15	206	51
1980	151	0	151	40

Sources: Figures on grain reserves from USDA, Foreign Agriculture Service, *Foreign Agriculture Circular*, FG-32-80, November 13, 1980, and USDA, Foreign Agriculture Service, private communication,December 2, 1980; figures on idled U.S. cropland from USDA, Agricultural Stabilization and Conservation Service, published and unpublished data received in private communication, February 5, 1980.

1975, when reserves fell to 40 days of consumption after bad weather reduced the harvest, food supplies have not been this low since World War II. In 1981, with a good harvest in the United States helping to offset the third poor Soviet harvest in a row, carryover stocks are expected to increase, but only by the equivalent of a few days of consumption.

World food insecurity was exacerbated by the extension of agriculture onto marginal lands. While climate has changed little in recent years, the vulnerability to climatic anomalies is undoubtedly increasing. Meteorologist Kenneth Hare observes that "the Sahelian droughts in Africa, for example, had several predecessors over the previous 500 years. What has changed is the vulnerability of the human economy."[47]

Global food insecurity mounts inexorably as agriculture is extended into marginal areas because the food economy is now global. Although the Soviet Union "Virgin Lands" are a major source of bread for Soviet tables, they are in an area of light and highly variable rainfall, subject to crop failure in one year of every three or four. When the decision was made in Moscow to offset these periodic shortfalls by increasing imports, the instability that had been confined to the Soviet food economy began to affect the supply and price of food for the entire world.

Soil erosion also contributes to food supply instability. When the organic matter in soil is reduced as a result of erosion, the soil's water-retention capacity declines so that the land becomes more vulnerable to short-term dry spells. A study by the U.S. Center for Environmental Assessment Services showed that eroded soils that had a yield 30 percent less than a non-eroded control plot also had a yield that was

four times more vulnerable.[48] Too often, efforts to expand output by extending cultivation onto marginal land increase harvest variability and global food insecurity.

Another source of world food insecurity is the dependence of the entire world on North America for food supplies. This unhealthy dependence has both meteorological and political dimensions since both the United States and Canada are affected by the same climatic cycles and since heavy dependence on any two countries for grain vests these countries with extraordinary political power. Both the United States and Canada already embargo the export of grain under certain conditions. The United States halted grain shipments to both the Soviet Union and Poland in the fall of 1975 because grain prices at home were rising too fast while Canada refused to license wheat exports in 1975 until it could more precisely determine the size of the harvest.[49]

Stripped of its reserves, the international community can no longer be counted on to respond effectively to crop shortages in poor countries. During the 1950s and 1960s, the story was quite different. Then, the United States intervened unilaterally with food-aid shipments wherever famine threatened. For example, after consecutive monsoon failures in India in 1965 and 1966, the United States shipped a fifth of its wheat crop to that country two years in a row to avert famine.

The food scarcities and oscillating grain prices of the 1970s affected all countries, but the poorest ones suffered the most. One of the hardest hit was Bangladesh. With two poor harvests during the 1970s, Bangladesh saw death rates twice climb sharply. An estimated 427,000 lives were lost in 1971-72 and another 330,000 in 1974-75.[50]

India, too, was hard hit during the early 1970s. After a weak monsoon and a poor harvest in 1972, the Indian government discovered that the Soviet Union had tied up most of the world's exportable wheat supplies, leaving little for India to use to offset its poor harvest. Thus, the Indian government sat by helplessly while food consumption fell and death rates climbed. The increase in death rates above the previous year in the three poorest states of Uttar Pradesh, Bihar, and Orissa claimed an estimated 829,000 lives.[51] This loss of life in India alone far exceeded the total combat fatalities suffered in any war since World War II.

UNICEF

Prolonged drought in the Sahel during the early 1970s brought the deteriorating African food situation into sharp focus.

During the early 1970s, hunger also took a heavy toll in Africa, where a prolonged drought in the Sahel brought the deteriorating food situation into sharp focus. Senegal, Mauritania, Niger, Upper Volta, Chad, and Mali—all lost lives. No one knows exactly how many died of starvation and hunger-related disease, though Cornell nutritionist Michael Latham testified before the U.S. Congress that the number may have been in excess of 100,000.[52] Further east in Africa, the ecological deterioration in Ethiopia's food system was also made

all too apparent by a drought that claimed an estimated 200,000 lives and helped bring Haile Selassie's 47-year reign to an end in 1974.[53] In Somalia, too, thousands died of severe malnutrition and disease in 1975; many of them perished after they reached relief camps.

Although grain stocks were partially rebuilt in the late 1970s after these calamities occurred in Africa and Asia, the global balance of supply and demand remains delicate, as the sensitivity of commodity prices to weather reports indicates. Now a poor harvest in a major producing country can set off a wave of global inflation. In poor countries, where rising food prices can push death rates upward, reduced harvests can have a demographic, as well as an economic, impact.

Following the grim experiences of the early 1970s, the United Nations convened a World Food Conference in Rome in November 1974. In addition to the general agreement on a greater effort to expand world food output, there was also agreement on the need to create an international food reserve as a buffer against emergencies. In 1980, after years of negotiation, a Food Aid Convention was concluded under the World Food Program administered by the United Nations and FAO to establish a modest reserve of 7.6 million tons of grain to assist countries experiencing severe food shortages. Four million tons of this is guaranteed by the United States under the 1980 Food Security Act.[54] This aside, the international community has made little progress in building an effective reserve for food aid.

Land Productivity Trends

In a world where close to 80 million new residents are added each year and where little fertile land awaits the plow, land productivity is the key to the food prospect. From the beginning of agriculture until World War II, productivity edged upward only slowly, sometimes remaining static for long stretches. Rice yields in 19th century Japan, for instance, were only marginally higher than those obtained during the 14th century. U.S. corn yields during the 1930s were no higher than those during the 1860s, the first decade for which reliable yield estimates are available.

Following World War II, however, crop yields began to rise in a sustained systematic fashion in virtually every industrial country. During the 1960s, the introduction of the semidwarf, fertilizer-responsive varieties of wheat and rice of the green revolution also enabled many Third World Countries to raise food output per hectare. Between mid-century and the early 1970s, the steady rise in cereal yield per hectare was one of the most predictable trends in the world economy, increasing at an average of 2.2 percent annually. Since 1970, however, the rate has fallen to 1.5 percent per year (see Table 8).

Numerous factors appear responsible for the slower rate of yield increase. In the great majority of situations, the new cropland being brought under the plow is of lower quality than the land already in use. Often the marginal land added replaces the prime land that is continually being withdrawn for nonfarm uses, leading to a reduction in land quality that is not evident from data on overall cropland area.

Also sapping farmland productivity is the reduction of fallow area in dryland farming regions. As world wheat prices rose between 1969 and 1974, U.S. summer fallow land dropped from 17 million hectares to 13 million.[55] This shrinkage led Kenneth Grant, then head of the Soil Conservation Service, to warn farmers that the other side of the lure of record wheat prices and short-term gains is the sacrifice of the land's long-term productivity.[56] The stresses are evident in other dryland farming regions as well. The U.S. Agricultural Attache in Moscow reported a similar

Table 8. World Production Harvested Area, and Yield of Cereals: 1950-1980

Year	Production (million metric tons)	Area in cereals (million hectares)	Yield (metric tons per hectare)
1950	631	601	1.05
1960	863	682	1.26
1970	1,137	704	1.62
1980	1,432	758	1.89

Source: USDA, Economics, Statistics and Cooperatives Service, unpublished data.

reduction in fallow land in the Soviet Union from 17 million hectares to 12 million after the massive crop shortfall and heavy imports of 1972.[57]

In tropical and subtropical regions, where fallowing has evolved as a method of restoring fertility, mounting population pressures are forcing shifting cultivators to shorten rotation cycles and thus to undermine the land's productivity. For example, in Nigeria, where farming has been expanded onto marginal land and fallow cycles shortened, cereal yields have been falling since the early 1960s. A World Bank study of Nigeria reports that "fallow periods under shifting cultivation have become too short to restore fertility in some areas."[58] In some locales, the original cropping cycle of ten to 15 years has already been reduced to five.

While the shortening of fallow cycles is reducing land productivity in some countries, soil erosion is reducing it in others. One of the big unknowns facing agricultural analysts is how rapidly excessive soil erosion will reduce land productivity. If this erosion continues in the U.S. Corn Belt, the U.S. Department of Agriculture estimates that "potential corn and soybean yields would probably be reduced by 15 to 30 percent on some soils by the year 2030." A study of the erosion of Piedmont soils in Georgia showed a six-inch loss of topsoil reducing average yields 41 percent. A similar degree of erosion in western Tennessee led to a 42 percent drop in corn yields.[59]

Some agricultural scientists believe that inherent biological constraints will eventually restrict crop yield per hectare. One analyst of this issue, Louis Thompson, Associate Dean of Agriculture at Iowa State University, has plotted the average corn yields recorded on several experimental stations in Iowa from 1958 to 1972, as well as those achieved by the state's farmers.[60] In the late 1950s, the gap between average yields on experimental plots and those on working farms was wide, but by the early 1970s it had virtually disappeared. In effect, the backlog technology has been largely used up and Iowa farmers are literally looking over the shoulders of the agricultural scientists working the experimental plots.

Norman Borlaug reaches an even more sobering conclusion. For wheat, corn, rice, and sorghum, which together with barley are the world's major cereals, as well as for soybeans, a leading feedgrain, he believes that agronomists "have reached a maximum genetic yield barrier that is difficult to break through. Future increases in genetic yield potential will be of smaller and smaller increments, and they will be more and more difficult to achieve."[61]

While enormous opportunities for

raising cropland productivity exist in some Third World countries, the outlook for further dramatic worldwide increases appears less hopeful now than at mid-century. Soil erosion is lowering the inherent fertility of one-fifth or more of the world's cropland. The backlog of new technologies developed in agriculturally advanced countries to increase potential crop yields is dwindling as is the response of crops to increased applications of fertilizer. Together, these factors cast a formidable shadow over the prospect of a continuing rapid rise in land productivity.

The Grain-Livestock Economy

Although most of the world's 1.4 billion ton annual grain harvest is consumed directly, a substantial share is consumed indirectly as livestock products. In the absence of religious restrictions on diet, the consumption of meat, milk, and eggs invariably rises with income. This whetted appetite for animal protein, in turn, translates into increases in grain fed to livestock. When world grain supplies are short, the competition between people and livestock for grain becomes acute.

Although corn and some other grains are used largely as feed and others, such as wheat, primarily as food, all grains can be used for either purpose —an important fact in view of recent per capita consumption patterns. As of 1979, annual grain use per capita ranged from roughly 160 kilograms in countries such as India and Kenya to just over 800 kilograms (1,760 pounds) in the United States and the Soviet Union.[62] The high end of this scale quite literally represents the fat of the land. The lower end is determined by minimal survival requirements. If consumption drops below 160 kilograms per year (roughly a pound of grain per day), malnutrition becomes severe and mortality rates begin to climb.

As their incomes rise, people eventually consume more grain indirectly—in the form of livestock products—than directly as cereal, flour, and other food. In the United States, Canada, and other affluent countries, some three-fourths of the grain used is converted into livestock products. In India, China, and other countries where the grain supply per person barely sustains survival, no more than 2 percent of the available grain supply is converted into animal protein.[63] In Japan, the United Kingdom, and Brazil—the middle ground—roughly half the grain used is fed to livestock.

Despite rising affluence in industrial societies and among Third World elites, the share of the world grain harvest fed to livestock has remained remarkably stable in recent decades. In 1960, livestock and poultry consumed 255 million metric tons of grain, or roughly 31 percent of the 835 million tons consumed for food and feed. The overall numbers were larger in 1979—450 million tons of a 1.426 billion ton total—but the share, at 32 percent, was virtually unchanged. The balance held because the increase in the grain used for feed was offset by population growth, which increased that used for food. During the third quarter of this century, consumption of beef, pork, mutton, and poultry increased in almost all industrial countries. Among those with the highest annual consumption per person in 1978 were the United States, France, and Poland (see Table 9). In sharp contrast, China, India, and other populous nations have few resources to spare for the production of animal protein.

While the amount of meat consumed is determined by income, the type of meat is influenced by population-land ratios. Those industrial countries that consume mostly beef have extensive grazing land—the United States, Canada, the Soviet Union, Australia, Argentina, and Brazil. In industrial countries that are most densely populated, such as those in both Western and

Table 9. Meat Consumption Per Capita in Selected Countries: 1978

(Numbers in kilograms per person)

Country	Beef and veal	Pork	Mutton, lamb and goat	Poultry	Total
United States	56	28	1	26	111
France	32	34	4	16	86
Poland	19	48	1	11	79
USSR	25	14	4	8	51
Brazil	18	7	—	7	32
Japan	5	12	2	10	29
China	2	15	1	3	21
Egypt	4	—	1	3	8
Nigeria	3	—	1	2	6
India	0.3	0.1	0.5	0.2	1.1

Sources: Compiled by Worldwatch Institute, using 1978 population figures from UN, *World Population Trends and Prospects by Country, 1950-2000*; data for China, Egypt, and Nigeria, and poultry data for India from FAO, *Production Yearbook 1978* (Rome: 1979), adjusted for trade using data from FAO, *Trade Yearbook 1978* (Rome: 1979); other data on red meat from USDA, *Foreign Agriculture Circular*, FLM 5-80, August 1980; and other data on poultry from USDA, *Foreign Agriculture Circular*, FPE 3-80, July 1980.

Eastern Europe, pork dominates. Pork is also the dominant red meat in East Asian countries such as China and Japan.

The efficiency with which grain is converted into meat varies widely by country. For example, although per capita grain use is just over 800 kilograms (food and feed) in both the United States and the Soviet Union, those 800 kilograms provide each American consumer with 111 kilograms of meat and each Soviet only 51 kilograms. The far better managed American farms get more than twice as much meat as Soviet farms do from a ton of grain.[64]

One way of increasing meat production when feed supplies are tight is to switch to those animals such as chicken that convert grain into meat most efficiently. This trend, now worldwide, helps explain why poultry production has outstripped that of other types of meat over the past decade or so. In the United States, where chicken was a Sunday dinner treat less than a generation ago, poultry consumption has now climbed above 26 kilograms per person per year (Table 9).

In spite of efforts to raise the efficiency of grain conversion into livestock products, competition between people and livestock for scarce grain supplies seems certain to intensify as pressures on the world's agricultural resource base increase. While the growing demand for animal protein has not so far raised the share of the grain harvest fed to livestock, it has generated an enormous demand for soybean meal for livestock rations. Since 1950, the world soybean harvest has multiplied fivefold, climbing from 18 million tons to 85 million.[65] In the United States, where the soybean was introduced from China, acreage in soybeans now rivals that in corn and wheat and soybeans rank first among agricultural commodities in foreign exchange earnings.

As rising affluence has converted the global appetite for livestock products into effective demand, the market for soybeans—an ideal protein complement to cereals in livestock and poultry rations—has grown rapidly. Growth has been particularly rapid since 1970 when the world fish catch leveled off. Between 1970 and 1980, the world soybean harvest doubled from 42 million tons to 85 million tons, with nearly all the increase being consumed by livestock.

While the Chinese harvest of nine million tons is used almost entirely for food, much of it as bean curd (*tofu*), most of the far larger U.S. and Brazilian soybean crops are used for feed, either domestically or when shipped abroad. An estimated two-thirds of the world harvest is now consumed as soybean meal, principally by livestock.[66]

What do these dietary patterns and trends say about the world food supply-demand equation? First, a vast potential for increased grain use for livestock feed exists in low-income countries if purchasing power permits. Indeed, the World Bank reports that middle-income developing countries (with a per capita Gross National Product above $370 in 1979) have increased their use of grain for feed by 10 percent per year since 1970 and these countries accounted for almost all of the doubling of developing countries' net grain imports during the 1970s to 52 million tons in 1980-81.[67] Second, in the event of a dire world food emergency, millions of tons of grain and soybeans could be diverted from feed to food use. In fact, diverting only a quarter of the world soybean harvest from feed use to direct human consumption would provide five kilograms per year of a high protein food for everyone in the world. The key here, of course, is making the shift before food prices have risen high enough to push up mortality rates among the world's poor —something the market is unlikely to do on its own.

The New Food-Fuel Competition

As the 1980s begin, the longstanding competition between food and feed is expanding to include fuel. In the past, the energy sector has supported the food sector, providing fuel for fertilizer and pesticide production, tillage, harvesting, crop drying, irrigation, and numerous other farm-related processes. With energy subsidizing agriculture, the earth's population-sustaining capacity increased dramatically. But now, as the shortage of liquid fuels grows, energy producers are beginning to compete with food producers for limited agricultural resources.

In the rush to develop indigenous liquid fuels to replace imported oil, alcohol distilled from farm commodities has emerged as a short-run alternative. Several countries have already launched agriculturally based alcohol fuel programs. Brazil, the United States, and the Philippines have major programs to convert agricultural commodities into alcohol for use as an automotive fuel, while Australia, New Zealand, and South Africa have programs either in operation or on the drawing board. For countries buffeted by soaring oil prices and fearful of supply disruptions, the prospect of an indigenous substitute for some of the imported oil is reassuring, but it means that automobiles now compete with people and livestock for the harvest.

Until recently, the claims of the poor and the affluent on the earth's agricul-

USDA/Fred Witte

A cattle feedlot in Texas. In a dire world food emergency, millions of tons of grain now fed to livestock could be diverted to direct human consumption.

tural resources have not diverged by more than a factor of five—the difference between an affluent diet rich in livestock products and a grain-based subsistence diet. If energy crops are figured in, however, the ratio increases dramatically since an automobile run on alcohol requires far more grain than a person does. Satisfying the annual food needs of a typical Third World consumer requires roughly one quarter of an acre of cropland, whereas the more affluent diet in an industrial society requires nearly an acre. By contrast, a typical American car fueled entirely by ethanol would require processing over seven tons of grain per year—the output from nine acres of average grain land.[68] In Western Europe, where cars are more fuel-efficient and are driven less, the typical automobile could be run on a little over three tons of grain per year. These numbers are in a sense hypothetical because no country except Brazil is running automobiles exclusively on alcohol and because grain is by no means the only commodity from which alcohol can be made. Nonetheless, the figures do indicate how quickly alcohol fuel programs could absorb vast amounts of grain.

Providing gasohol (a blend of one part alcohol to nine parts of gasoline from oil) for the typical U.S. car would each year require 1,460 pounds of grain, or slightly less grain than the average American annually consumes directly and indirectly as food. Accordingly, the cropland requirements of an American car owner who switches to grain-based gasohol would nearly double—rising from .9 to 1.7 acres. To the degree that the protein-rich by-product of the distillation process—distiller's dried grain—can be used successfully as livestock feed, the land requirement could be reduced. But if liquid fuel is used to produce and distill the grain, more land will be required to produce sufficient net amounts of liquid fuel. In the second case, headway toward reducing oil imports will be made two steps forward, one back.

Brazilian agricultural officials argue that energy crops will be produced in addition to, rather than instead of, food crops. In fact, though, energy crops compete not only for land but also for agricultural investment capital, water, fertilizer, farm-management skills, farm-to-market roads, agricultural credit, and technical advisory services. Only in a centrally planned economy, where all agricultural inputs are carefully controlled and clearly tagged for the production of either food or energy, could a major energy-crops program be launched without siphoning resources away from food production. Brazil's case is quite different. It may well reach its national goal of liquid fuel self-sufficiency by 1990 but have more hungry people than it does today.

The immediate consequences of the Brazilian energy-crops program may be more internal than external, but the more recently launched effort in the United States has broader ramifications. In January 1980, the White House announced a goal of increasing ethanol production to two billion gallons per year by 1985. Meeting this goal would require distilling some 20 million tons of grain or roughly one-fifth of the U.S. exportable surplus. The traditional buyers in the North American grain market—the flour millers, the feedlot operators, and the grain-importing countries—may be outbid by alcohol fuel distillers, who are the beneficiaries of generous tax exemptions and other subsidies that can exceed a dollar per gallon.[69] As alcohol distilleries gradually replace oil refineries, more and more farmers in the United States and elsewhere will have to choose between producing food for people and fuel for automobiles. They are likely to produce whichever is the more profitable. In such a situation, the price of oil will eventually set the price of food.

For food-exporting countries, the immediate appeal of converting exportable food surpluses into alcohol fuel is

undeniable. But in a world that has little if any excess food-producing capacity, channeling foodstuffs into automobile fuel production will inevitably drive food prices upward. For the world's affluent, such rises in food prices may lead to belt tightening. But for the several hundred million people who are already spending most of their meager incomes on food, rising food prices will further narrow the thin margin of survival.

The Food Price Prospect

As the demand for food continues to press against the supply, inevitably real food prices will rise. The question no longer seems to be whether they will rise but how much. Since 1970 the growth in world grain production has unmistakably lost momentum. Expanding at well over 3 percent per year during the 1950s, growth fell to just over 2 percent annually during the 1970s.

In efforts to eliminate hunger, this loss of momentum is aggravated by the heavily skewed distribution of income both within and among countries. Incomes among the wealthier one-fifth of humanity are easily 20 times those of the poorest one-fifth. Similar ratios exist between the wealthiest and poorest fifths within societies where wealth is concentrated in a few hands, such as Iraq, Senegal, Brazil, Ecuador, and Mexico. Without effective efforts to redistribute income, meaningful progress in the eradication of hunger is unlikely.

The worldwide loss of agricultural momentum is serious in itself. But more serious are the gathering forces behind this loss. It is becoming ever more difficult to expand the cropland base, and soil erosion's toll on productivity is continuing unabated. Returns on the use of chemical fertilizer at the margin are also diminishing. Each of these forces promises to become an even stronger drag on the growth of food production during the 1980s.

Table 10. International Prices of Wheat and Oil: 1950-1980

Year	Wheat price (dollars per bushel)	Oil price (dollars per barrel)	Bushels of wheat to buy a barrel of oil
1950	1.91	1.71	1
1955	1.77	1.93	1
1960	1.58	1.50	1
1965	1.62	1.33	1
1970	1.50	1.30	1
1971	1.68	1.65	1
1972	1.90	1.90	1
1973	3.81	2.70	1
1974	4.90	9.76	2
1975	4.06	10.72	3
1976	3.62	11.51	3
1977	2.81	12.40	4
1978	3.48	12.70	4
1979	4.36	16.97	4
1980 (prel.)	4.70	30.50	6

Source: Compiled by Worldwatch Institute from data in International Monetary Fund, *International Financial Statistics 1980* (Washington, D.C.: 1980); and author's estimates for 1980.

It is tempting to look to science and technology for help. But at the moment new agricultural technologies provide only small comfort. Hopes run high for increasing the photosynthetic efficiency of major crops and for developing cereals that can fix nitrogen so chemical fertilizer use can be reduced. But these advances represent major feats of biological engineering, feats that cannot be taken for granted. If commercial nitrogen-fixing cereals become a reality, they will reduce energy requirements in agriculture but not necessarily increase output. Moreover, beyond these two possibilities there does not appear to be anything on the technological drawing board that could lead to quantum jumps in world food output. We cannot expect gains such as those made possible in postwar agriculture by

the use of chemical fertilizer, improved seeds, and irrigation.

Perhaps more than anything else, the price of food will be influenced by oil price rises. From 1950 to 1972, for example, both the price of a bushel of wheat and that of a barrel of oil hovered around $1.80 (see Table 10). Throughout this period, a bushel of wheat could be traded for a barrel of oil. But after the price of oil began its rapid climb in late 1973, it left the comparatively stable price of wheat far behind. In 1980, it took six bushels of wheat to pay for a barrel of oil. Now there are signs that food prices may begin a long-term climb as well. Even as the price of liquid fuels required for farming rises, agriculture is seen by more and more governments as a source of liquid fuels. With hundreds of large distilleries newly on line, under construction, or in the planning stage, the diversion of agricultural resources to automotive fuel production could escalate rapidly. In 1980, Brazil devoted nearly one million hectares of cropland to the production of sugarcane for automotive fuel; the United States used some 80,000 hectares to produce grain that was converted into alcohol fuel; and the Philippines started marketing "alcogas" made from sugarcane.[70]

The sharp shift in the terms of trade between oil and grain tempts populous, oil-exporting countries that are having problems in agriculture to import more food. For these countries, which include the Soviet Union, Nigeria, Mexico, and China, the terms of exchange between oil and grain are exceedingly attractive, and they are rapidly expanding their food imports as the 1980s begin. This extraordinary leverage in the world grain market is driving food prices upward far more rapidly than was possible when a barrel of oil and a bushel of wheat had the same value. In effect, the price of oil is gradually pulling the price of food upward in its wake.

This new relationship between the food and energy sectors makes food projections more complicated than ever before. The principal cushion now remaining in the world food economy is the grain that is fed to livestock. This grain could easily be made available for human consumption in times of shortage, though so far it has been diverted from livestock only when the price climbs to a level that induces widespread starvation.

The food price prospect inspires concern. Just as the 1970s dramatically underscored the new energy realities, the 1980s promise to do the same for food. Indeed, rising food prices may become a more or less permanent feature of the economic landscape in the years ahead. Few, if any, economic indicators are as politically sensitive as food prices.

Stabilizing Population: A First Essential

Mounting pressures on food resources in a world of 4.5 billion people suggest that, if population growth continues as projected, a decline in food consumption and material living standards the world over may be unavoidable.

Current UN medium-level population projections, used by planners throughout the world, show global population expanding to 10.5 billion before stabilizing in the year 2110.[71] The latest World Bank projections put the stabilized total only slightly lower at 10.1 billion.[72] Both sets of projections assume that the fertility decline now evident in many developing countries will continue and spread as economic and social development occurs. The World Bank projects phenomenal growth for many countries already hard pressed to feed their populations. India, for example, is projected to add nearly another billion to its estimated 1980 population of 673 million before stabilizing at 1.62 billion, while neighboring Bangladesh and Pakistan

are expected to increase from 92 million and 82 million in 1980 to 338 million and 340 million. Nigeria's 1980 population of 85 million is projected to increase to 459 million, almost as many people as now populate all of Africa, and Mexico's population would increase from 67 million in 1980 to 203 million, not far below the U.S. 1980 population of 227 million.

These projections are based on assumptions about future fertility levels, sex ratios, life expectancies, and other demographic variables. If these explicit assumptions hold, then the projected increases in world population will materialize. But population growth does not occur in a vacuum. The projections also assume implicitly that supplies of food, energy, and the other natural resources needed to support human life will continue to be available. To be realistic, demographic models need to incorporate feedback mechanisms that reflect how attitudes toward population size might change as the stresses associated with continued population growth materialize.

Already we know that population demands are leading to exhaustion of soils in many locales and there is the prospect of a downturn in world per capita grain production. During the early 1950s, the annual growth in world grain production was nearly double that of population, but since then, grain production's edge over population has fallen from 1.2 percent annually to 0.5 percent in the 1970s (see Table 11), even with the return of idled U.S. cropland to production. If the growth in grain production continues to slow, it could fall below population growth worldwide, as it already has in Africa. We also know that the per capita fish catch began to decline as world population reached 3.6 billion in 1970 and beef output per person stopped growing as population reached four billion in 1976.

At what level, then, should we aim to stabilize world population? Demographers point out that even if fertility were to fall immediately to replacement level (the births needed for a given generation to replace itself, or 2.1 to 2.5 births per woman, depending on a country's mortality conditions), population would continue to grow for several decades in those countries with many young people in or about to enter the reproductive ages. This means that if population growth is not to be slowed by rising mortality, fertility may have to drop well below replacement level in some societies, with one-child families becoming the norm. The stresses this might cause must be weighed against the costs of failing to halt population growth in time to avoid collapse of the earth's food-production system. The sum of stresses on both sides might be minimized if world population growth could be brought to a halt somewhere around six billion. Supporting even six billion people at acceptable consump-

Table 11. Growth in World Grain Production by Decade, Total and Per Capita: 1950-1980

(Numbers in percent)

Decade	Decade rate	Annual rate	Annual rate per capita
1950-60	36	3.1	1.2
1960-70	32	2.8	0.8
1970-80	26	2.3	0.5

Sources: Compiled by Worldwatch Institute using unpublished data on grain production from USDA, Economics, Statistics and Cooperatives Service; and population figures from UN, *World Population Trends and Prospects by Country, 1950-2000.*

Table 12. Countries with Essentially Stationary Populations: About 1981

Country	Mid-1981 population (millions)	Birth rate (per 1,000 population)	Death rate (per 1,000 population)	Annual rate of change[a] (percent)	Annual change[a] (number)
Austria	7.5	12.0	12.2	-0.02	- 1,500
Belgium	9.9	12.6	11.4	0.12	+11,500
Denmark	5.1	11.2	10.9	0.03	+ 1,400
East Germany	16.7	14.0	13.9	0.01	+ 2,500
Luxembourg	0.4	11.7	11.5	0.02	+ 100
Sweden	8.3	11.7	11.0	0.07	+ 5,200
United Kingdom	55.9	13.1	12.1	0.10	+59,000
West Germany	61.3	10.0	11.5	-0.15	-93,700
Total	165.1				-15,500

Note: Data on population change exclude both emigration and immigration.

Sources: Mid-1981 population from Population Reference Bureau, *1981 World Population Data Sheet;* all other data from UN, *Population and Vital Statistics Report, Data Available as of 1 April 1981,* Statistical Papers Series A, Vol. 33, No. 2 (New York: 1981).

[a]Data refer to 1979 or 1980 and were the latest available at time of going to press.

tion levels will not be possible without sharp increases in food production, widespread food rationing, and more equitable distribution of food resources both within and among societies. On the other hand, stabilizing world population at six billion will not require any country to reduce its birth rate any more rapidly than Barbados, China, Costa Rica, and Indonesia have over the last decade.

Stabilization at 6 billion: A timetable

Achieving a stabilized world population of six billion will have to occur in stages, with developing countries following a slower timetable than the industrial countries. For industrial countries, 2000 will be the target date for a stationary population with annual births and deaths in balance. Eight European countries, in fact, already have essentially stationary populations, as seen in Table 12. The populations of Austria and West Germany are actually declining. To the extent that some industrial countries achieve stability ahead of schedule, others can lag accordingly without disrupting the overall timetable.

For the developing world, population would have to be stabilized in four decades instead of two. The first step would be to reduce the average birth rate from 32 per 1,000 population (the 1980-81 level for developing countries as a whole) to 26 by 1990. Each decade thereafter the rate would drop by 5 until reaching 11 in 2020, roughly the same as in Denmark, Sweden, or West Germany in 1980. The crude death rate would remain at the overall Third World 1980 level of 12 until 1990, rather than continuing the postwar decline, largely as a result of higher food prices and severe nutritional stress. With Third World population growth slowing from 1.4 percent in 1990 to 1.0 percent in the year 2000, the enhanced potential for improving nutrition would permit the death rate to drop to 11, where it would stay until stabilization is reached in 2020. While some further improvement in living conditions would lower the death rate further, this would be offset by the aging of the population that follows a sustained decline in fertility.

Lowering the average birth rate in

developing countries to 26 by 1990 will require a Herculean effort, but some are already far ahead of schedule. Birth rates are now 25 or below in Taiwan and South Korea, and below 20 in Barbados, Cuba, Hong Kong, Singapore, and in the key country of China, with one-third of the developing world's population. The two score African countries with birth rates from 40 to over 50 will be hard pressed to meet the target, but if their growth is not checked soon, the famine which claimed hundreds of thousands of lives in the early 1970s could well return.

Under this timetable, world population growth would be reduced to 1.1 percent in 1990, 0.8 percent in 2000, 0.4 percent in 2010, and zero in 2020 (see Table 13). The timetable is admittedly ambitious, but attitudes toward family size are changing and birth rates are stationary or falling almost everywhere. Should the world fall far behind the stabilization timetable, population pressures could become unbearable, leading to widespread collapses of local biological life support systems and of social systems that depend on them. In this event, population growth would be checked by rising death rates rather than declining birth rates as scheduled in the timetable.

Thus far, much of the global decline in population growth is concentrated in a few of the world's most populous countries. China, with 985 million people—over one-fifth of the world's population in 1981—and only a quarter of an acre of cropland per person, reportedly reduced its growth rate from 2.3 to 1.2 percent between 1971 and 1978. Now it has stepped up its already comprehensive "birth planning" program with a campaign to promote the one-child family, aiming for a zero-growth population in 2000 and an actual decline in total numbers after that.[73]

A second sign of hope is the United States, which ranks fourth in population with 230 million at mid-1981. Here population growth fell by a third between 1970 and 1975 although the birth rate was expected to rise when the post-war baby boom children entered their prime reproductive years.[74] An unanticipated drop in the marriage rate, steady growth in female employment, a sharp upturn in female enrollment in graduate and professional schools, and other social changes no doubt contributed to this turn of events.

In Indonesia, the world's fifth most populous country with 149 million in 1981, growth rates have fallen markedly in Bali and parts of Java where a strong community-based family planning program was launched in the early 1970s.[75]

Currently, 27 countries have fertility rates at or below replacement level (Table 14). Including the eight European countries already at zero growth and China, a recent addition to the list if its official statistics are accurate, these countries contain more than 1.7 billion people, or nearly 40 percent of the world total. Once fertility settles at the replacement level or below, it is only a matter of time until population growth stops. Although some countries with large proportions of young people may then require generations to reach equilibrium, it is now clear that replacement-level fertility can be attained by countries with widely varying income levels, cultures, and religions. This suggests that world population size can stabilize at a level far lower than that

Table 13. A Proposed Population Stabilization Timetable

Year	World population (billions)	Annual growth rate (percent)	Annual increase (millions)
1970	3.6	1.9	69
1980	4.4	1.7	75
1990	5.0	1.1	55
2000	5.5	0.8	44
2010	5.8	0.4	23
2020	6.0	0	0

Source: Worldwatch Institute.

Table 14. Countries with Fertility at Replacement Level or Below: 1979

Country	Total fertility rate[a] 1979	Mid-1981 population (millions)
Austria	1.6	7.5
Australia	2.0	14.8
Barbados	2.2	0.3
Belgium	1.7	9.9
Bulgaria	2.1	8.9
Canada	1.8	24.1
China	2.3	985
Cuba	1.9	9.6
Denmark	1.6	5.1
East Germany	1.9	16.7
Finland	1.6	4.8
France	1.9	53.9
Hungary	2.0	10.7
Italy	1.7	57.2
Japan	1.8	117.8
Luxembourg	1.5	0.4
Malta	2.0	0.3
Netherlands	1.6	14.2
Norway	1.8	4.1
Portugal	2.0	10.0
Singapore	1.8	2.4
Sweden	1.7	8.3
Switzerland	1.5	6.3
United Kingdom	1.9	55.9
United States	1.8	229.8
West Germany	1.4	61.3
Yugoslavia	2.2	22.5
Total		1,742.0

Source: Population Reference Bureau, *1981 World Population Data Sheet*.

[a]The total fertility rate (TFR) indicates the average number of children that would be born to each woman in a population if each were to live through her childbearing years (ages 15-44) bearing children at the same rate as women actually did in a given year. A TFR of 2.1 represents replacement level in populations with a life expectancy at birth of about 70 years or more. In China, with a life expectancy at birth estimated at 65-68 years, a TFR of about 2.3 would be replacement level. China's TFR was officially estimated at 2.3 for 1979, but many observers believe the actual TFR is currently higher.

projected by the United Nations or the World Bank, and good sense indicates that it must.

Toward lower fertility

Providing family planning services to all who want them is one of the most obvious ways governments can help slow population growth. Despite steady progress over the past decade in expanding contraceptive services, only 270 million of about 900 million couples in the world of childbearing age are using modern contraceptives—90 million of them in the developing world—according to estimates released at the International Conference on Family Planning in the 1980s, held in Jakarta in early 1981.[76] Data becoming available from the World Fertility Survey also reveal a vast unmet desire and need for contraception. In the first 15 to report of 41 developing countries participating in the WFS, the desire to cease childbearing among married women of reproductive age ranged from 30 percent in Nepal to 72 percent in Korea.[77] From an analysis of WFS data for Colombia, Panama, Peru, Indonesia, Korea, and Sri Lanka, demographer Charles Westoff concludes that "the prevention of unwanted births . . . would reduce fertility by one-quarter to one-third in five of the six countries."[78]

Providing contraceptive services does not guarantee that they will be used. But where the demand has preceded their availability, the initial provision of services has led to a sharp decline in birth rates, as happened in Costa Rica, where the birth rate fell from 47 in 1961 to 28 in 1973.[79] As family planning services become available, they tend to generate additional interest and demand. In rural areas of Mexico, the expansion of family planning services increased awareness of where they could be obtained from 26 percent in 1976 to 60 percent in 1978, and this awareness was closely related to their actual use.[80]

WFS data and experience show that, to be widely used, contraceptive services should be within 30 minutes' travel time for the user and either free or

cheap. The more successful family planning programs also offer a wide choice of both male and female contraceptive methods and, as in Indonesia and China, involve the community in setting birth rate goals, designing the program, and delivering services. To achieve a stationary population, contraceptive services will also have to be backed up by readily available, legal abortion—a basic public health service still denied to one-third of the world's women.[81]

While most political leaders at least acknowledge the threat of continued population growth, only $1 billion a year is currently being spent on Third World family planning and population programs by national governments and international assistance agencies. The Jakarta Conference on Family Planning in the 1980s urged that this be raised to an annual $3 billion—still a paltry sum compared to the $480 billion of world military expenditures in 1978, the latest year for which such data are available.[82]

Based on European experience in the late 19th and early 20th centuries, demographers have argued that social and economic progress is necessary before birth as well as death rates will fall. Now, however, fertility declines in many developing countries appear to be largely independent of social or economic improvement. Demographer Michael Teitelbaum points out, moreover, that the modest level of development that most Third World countries can aspire to will not be sufficient to stabilize population size.[83]

Of all social indicators, the one that correlates most closely with fertility decline is a rising level of education. World Fertility Survey data from 20 developing countries show that women and men who have a primary education have fewer children than those who do not.[84] Better educated women are also more likely to marry later and to work outside the home and both these factors are associated with lower fertility.

Besides ensuring ready access to

UNICEF/Jacques Danois

Village midwives receive family planning training in Indonesia where a strong community-based family planning program was launched in the early 1970s.

family planning services and improving social conditions, governments can also use public policy to encourage smaller families. Singapore, a pioneer in this approach, has revised regulations on housing, taxes, schooling, and maternity leave to discourage more than two children per family and has reduced its fertility rate to 1.8 children per woman. The Philippines limits to four the number of children for whom tax deductions can be claimed and Nepal has eliminated deductions for children altogether. China now offers many incentives to couples who pledge to have only one child, including pay raises, housing priority, extra grain rations, and higher than average pensions on retirement.

Other Essential Steps

While braking population growth is a first essential if food needs are to be met on a finite planet, much else remains to be done. Topping the list is

increasing crop yields in developing countries, the major alternative to increasing world food production now that there is little additional land that can be cultivated and crop yields are close to the maximum in agriculturally advanced nations.

Increasing Third World crop yields

Wheat and rice successes over the past decade in such countries as India, Pakistan, the Philippines, Turkey, and Thailand demonstrate that, given the right inputs, Third World farmers can increase yields dramatically. Chief among these inputs, according to Norman Borlaug, is chemical fertilizer used to restore fertility to soils "mined" by traditional agriculture.[85] Developing countries still use only 30 percent of the world's chemical fertilizer, although their share has increased from 19 percent at the beginning of the 1970s.[86] With soil fertility restored, new high-yielding, disease-resistant crop varieties are needed. Such new varieties now exist for corn, sorghum, and soybeans as well as for wheat and rice, though further improvements can still be made in such crops as barley, oats, millet, and root crops like cassava.

Water is another essential if yields are to reach their maximum. The world's irrigated cropland has increased from 157 million hectares in 1961-65 to 207 million in 1979, according to the FAO, but Africa's share of the total, for example, is a scant 1 percent.[87] Only 30 percent of India's cropland is irrigated, leaving most of the annual harvest still prey to the vagaries of the monsoon rains.[88] With sufficient water and high-yielding crop technology, farmers in India, the Philippines, China, Taiwan, and South Korea have also shown that yields can be escalated by growing two to four crops a year on the same land. Multiple cropping also provides more year-round employment in Third World rural areas where food now runs short in households of landless laborers laid off and without money to buy food between harvest and crop-planting seasons.

Traditional farmers must also be trained and encouraged to use new techniques: how and when to plant the new seeds; how to control weeds, insects, and disease; and how to conserve and manage water. At present, agricultural extension services to provide such training to Third World farmers are "frequently under-financed and inadequately staffed," notes the World Bank in its *World Development Report* for 1981. The Bank also notes, however, that "the improved productivity of small farmers" has been "the outstanding success of the 1970s" in world food production. "Their extra output has been the key to impressive growth in such countries as India, Indonesia, and Malaysia."[89] And yet many countries fail to provide adequate incentives to small farmers such as sufficient credit to cover seed, fertilizer, and pesticides until harvests come in, and guaranteed prices for their crops.

One hope for improving agricultural yields in developing countries lies in the research being done in a unique international network of agricultural research centers spawned by the success of research on corn and wheat in Mexico in the 1940s and 1950s and on rice in the Philippines in the 1960s. Funded by 35 national governments, international agencies, and private foundations through the Consultative Group on International Agricultural Research, the research ranges from improving the potato (focus of the Peruvian center); beans, cassava, rice, and beef (Colombia); dryland farming in the tropics (India); to food policy (Washington, D.C.).[90]

Better food distribution

Increasing food yields must be backed up by better distribution if the world's poor are to be more adequately fed than now—particularly the landless or

virtually landless in rural areas of the Third World. Most developing countries have some form of subsidized, publicly managed food distribution. Most of these schemes, however, are aimed at keeping food supplies reliable and cheap in urban areas, as the World Bank notes, and low ceiling prices on food can discourage farmers from increasing production.[91] India sells subsidized wheat, rice, and other grains in "fair price" shops and has had some success with "food-for-work" programs in rural areas. In some African countries, however, the limited supply of subsidized food has tended to go to "an increasingly small urban group—and rarely to those who need it most," the Bank notes.

Food subsidies that benefit mostly urban dwellers are part of the pro-urban bias implicit in much official policy of developing countries. Commonly, countries with 70 percent of their populations in rural areas will allocate only 20 percent of their public sector investment to the countryside.[92] This adds to the forces propelling the buildup of enormous urban agglomerations that increase the pressures on world food supplies. For each person who moves from the countryside to the city there must be a corresponding surplus of food produced in a rural area somewhere in the world. Since mid-century, more and more of the world's exploding cities —from Mexico City to Bombay, Cairo to Tokyo—have come to depend on North American grain shipments for at least part of their food supplies. As doubt grows that the recent growth in North American grain exports can be sustained, governments may be convinced that the time has come to abandon their urban bias.

Better food distribution also implies cutbacks in the diets of the affluent so more is available to feed the poor. In the United States, the heavy consumption of grain-fed steak has long symbolized the country's affluence. Now, along with the trend to smaller automobiles and other signs of simpler lifestyles, Americans have reduced beef consumption from 128 pounds per person in 1976 to 105 pounds in 1980, a fall of some 18 percent in just four years. This has been motivated in part by self-interested efforts to reduce cholesterol intake and the risk of heart disease. The result, however, is to free resources that can increase consumption among the undernourished. In a world where the margin between food production and population growth is narrowing, people in the low-income countries will be able to consume more only if the world's affluent consume less.

World Bank/Ray Witlin

Harvesting rice in Rajasthan, India. Given the right inputs, Third World farmers can increase crop yields dramatically.

Preserving and restoring agricultural land

Halting farmland conversion and soil erosion and desertification are also crucial to meeting global food needs.

Several industrial countries now have land-use policies. Japan has divided the whole of its sliver of a country into zones and carefully restricts their use, whether agricultural, urban, or for forests and natural reserves.[93] Belgium, France,

the Netherlands, and West Germany have established national land-use guidelines and accorded responsibilities to local communities. France has an effective farmland preservation program run by local nonprofit societies empowered to buy and sell farmland in order to assist farmers to remain in farming or keep prime farmland from being subdivided.[94] In Canada, the province of British Columbia has passed legislation to preserve agricultural land.[95] In the United States, several states have launched programs to preserve farmland, although land-use planning on a national scale is so far restricted to setting aside national parks, forests, and wildlife reserves.

The United States, however, has now drafted a national plan for stemming topsoil loss.[96] Prepared by the Soil Conservation Service, the plan envisages converting 17 million badly eroded acres of the nation's 413 million acre cropland base to forest or grassland and adopting terracing, contour farming, strip cropping, reduced tillage, or other measures to protect another 141 million acres of cropland that are currently losing more than five tons of soil per acre per year. The cost of the program is estimated at $103 billion over the next 50 years. The program would raise food production costs and prices in the short run, and has not yet been adopted by the Reagan administration and congressional leaders. But it is the type of plan that a majority of the world's countries now need if their soils are to be stabilized.

In the world's semiarid regions, soil degradation translates into desertification. Israel's success in restoring parts of the Negev Desert to productivity shows what can be done to reverse the effects of thousands of years of overgrazing and deforestation. China, too, has been struggling to halt deterioration of its huge desert area and Algeria, Iran, Somalia, and Sudan have launched large-scale desert reclamation programs.[97]

Only governments' willingness to share the costs will induce farmers to adopt soil conservation measures whose immediate costs are three times the immediate benefits, as the Iowa study showed. In some countries, the expenditures required simply to stabilize soils will dwarf the total appropriations for agriculture. Yet the alternative is for governments to neglect the short-term deterioration and then face long-term food scarcity as the cropland base deteriorates.

Reducing food-fuel competition

To reduce the emerging competition between energy and food crops for land and other agricultural resources, the challenge is to use marginal land or crop by-products and vegetable matter that do not compete directly with food.

In Africa, Zimbabwe and Kenya have begun using molasses, a by-product of local sugar mills, to produce ethanol. South Africa, the world's leading producer of liquid fuel from coal, also plans to produce alcohol from cassava grown in the semiarid Makatini Flats in northern Zululand where little of agricultural value is now produced.

An undomesticated plant with a high hydrocarbon content that could yield oil for diesel engines and which is well adapted for soil unfit for agriculture is the *Euphorbia lathyris*, a desert shrub found in Mexico and the U.S. Southwest. Melvin Calvin of the University of California believes it could yield year after year the equivalent of 6.5 barrels of oil per acre.[98] Another potentially important energy plant is the "copaiba" tree of the Amazon which can be tapped for a liquid that can be used unprocessed in place of diesel fuel.

Research at North Dakota State University suggests that diesel fuel can also be replaced with sunflower seed oil.[99] Corn farmers could produce all the fuel for their tractors from sunflowers grown

on just 10 percent of their land, with the oil extracted on the farm by a simple mechanical crushing process.

Further U.S. research is exploring the potential for producing methane from water-based, energy-rich plants such as giant kelp, water hyacinths, and algae. Water hyacinths, which clog irrigation canals and reservoirs, could be fertilized with the nutrients from urban sewage, thus converting an otherwise wasted resource into usable energy at an impressive rate; one acre of sewage-enriched warm water can produce several tons of water hyacinths a day, enough to yield between 3,500 and 7,000 cubic feet of methane.[109]

Changing Values and Food Security

In the eight short years since the global food crisis of 1973, the underlying forces precipitating that crisis have become clearer. If civilization is to survive, the response must be a shift in age-old values and in the definition of what constitutes "national security."

Ironically, some of the values that have contributed to human survival over the last few million years, such as acquisitiveness and the desire for many children, are precisely those that now threaten survival. Acquisitiveness, a peculiarly human trait, may have served society well in earlier times when the margin of survival was thin. Continuous childbearing throughout the reproductive lifespan was also undoubtedly a key factor in the survival of the species. But now circumstances are changing and as they do, so must values.

A world that now has four and a half billion human inhabitants also desperately needs a land ethic, a new reverence for land, and a better understanding of the need to use carefully a resource that is too often taken for granted. Civilization cannot survive a continuing erosion of the cropland base or the endless conversion of prime farmland to nonfarm uses.

Over the last century, changing conditions in the industrial countries, particularly the decline in infant mortality, have altered attitudes toward family size, and as values have changed, birth rates have fallen. With 90 percent of all babies born in the world now surviving at least through their first year of life, stabilizing world population will require an acceleration of that process in many countries. As with other values, the key to spurring changes in attitudes toward family size is information. In China, this has taken the form of a population education campaign based on data on reduced infant mortality and on careful calculations of the amount of cropland per Chinese today compared to what it will be a generation or two hence if birth rates are not sharply reduced. A similar educational effort is being launched in Bangladesh.

New values regarding population growth and land are essential if world food security is to be assured. Food security in turn is part of redefining national security. Since World War II, "national security" has acquired an overwhelmingly military character. Underlying this definition is the assumption that principal security threats come from other countries. Yet, the threats to security may now arise less from the relationship of nation to nation and more from the relationship of humanity to nature. For many countries, desert encroachment or soil erosion may do more to undermine national survival than invading armies could.

Even though rapid population growth can destroy a country's ecological system and social structure more effectively than a foreign adversary ever could, national government expenditures on population education and family planning fail to reflect this fact. Countries spend large sums on tanks and planes to defend their territorial sovereignty, but little or nothing to protect the topsoil on which their livelihood depends.

National defense establishments are useless against these new threats.

We now know what needs to be done to ensure that all may be fed within the sustainable society that must be created if our civilization is to survive. Each of the actions that most countries must take has already been taken by a few. Several industrial countries have already brought their population growth to a halt. Birth rates in a number of Third World countries have dropped impressively. Japan, Belgium, France, the Netherlands, West Germany, and Canada are implementing national land-use policies. The United States has a national soil conservation plan on the drawing board. Israel has shown that deserts can be restored to productivity. India has increased wheat and rice productivity among millions of small farmers. Americans have reduced their beef consumption.

Collectively, each such effort, spurred by governments, businesses, public interest groups, and individuals in industrial and Third World lands alike, will bring us closer to ensuring that the food which is basic to human survival will be available for generations to come. □

Frontispiece photos (page 2): Peace Corps (bottom left); U.S. Department of Agriculture (top right); all others: World Bank photos by Ray Witlin.

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